

CHAPTER I

INTRODUCTION

1.1 Project Background

In this subsection, various stages involved in the PCB fabrication process are briefly described. In order to minimize scrap cause by the wrongly etched PCB panel, the automated visual inspection is proposed to be applied after the circuit printing and before the etching process. Also, 14 types of defect are outlined. These defects are expected to occur after the circuit printing process.

1.1.1 PCB Fabrication Process: An Outline

Aithal, et. al [1] gives the stages involved in PCB fabrication process in some detail. Following paragraphs briefly describe the stages involved in the PCB fabrication process. Figure 1.1 illustrates the various stages in the PCB fabrication process.

Boards with thin layer of copper on one side are used for fabrication of single-sided PCBs. These boards are cut into pieces. These pieces of board are called panels.

The input item for the PCB fabrication process is the artwork. Artwork is a film with the PCB pattern designed on it. Based on the artwork, stencil that is a mask of circuit pattern is built for circuit printing process. Here, the designed circuit pattern is printed over the copper foil with blue ink, which acts as etch resist for subsequent etching stage.

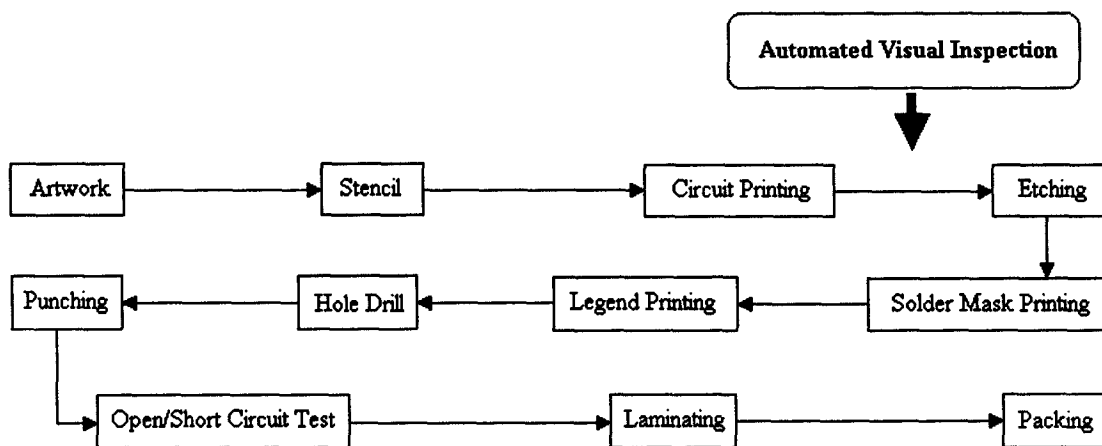


Figure 1.1 : PCB fabrication process

Once the circuit printing is done, the etching process takes place. This process is an irreversible process. Copper foil is etched by spraying the etchant to the panel as the panel moves on the conveyor. The etchant will bare the unwanted copper foil, which must be etched away to leave the copper pattern.

Solder mask (green ink) printing is needed to make sure there is no short circuit occurs during soldering. The solder mask is typically applied by screen-printing using solder mask film, which enables the entire board surfaces to be covered, except for the holes and pads. Next, the legend is screen printed onto PCBs to identify the components. This printing operation is performed using legend print film.

At the hole drill stage, the board is drilled with 2 minimum holes. These 2 holes are important for the alignment purpose either in assembly or inspection

process. Once the panel is drilled, the next stage is punching. Here, all necessary holes are created or punched. The punched board goes to electrical test to check if there is any open or short circuit occurs on the board. Finally, the PCB is laminated to prevent oxidation before packing.

1.1.2 Inspection

At various stages of the fabrication process, inspection is done. If the panel is accepted at that stage, it is passed on to the next stage. Otherwise, the panel goes back to rework, to the same stage of operation. But in some of the cases, the panel is rejected. For such cases, the panel inspection is critically important.

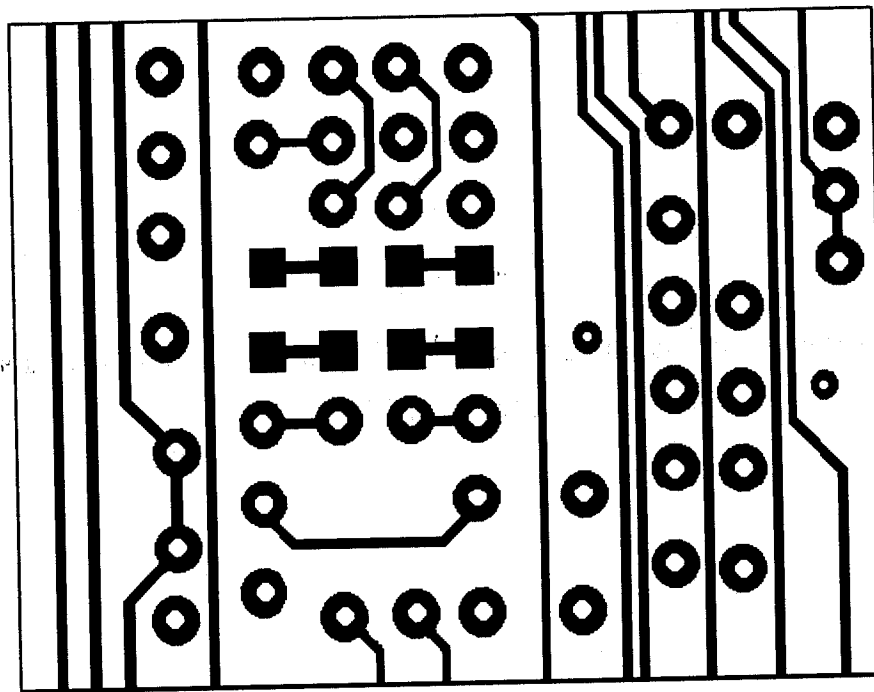
Current practice in PCB fabrication requires etching process. This process is an irreversible process. The printing process, which is done before etching process, caused most destructive defects found on the PCB. Any misprint will cause the etched board to be useless. Since laminated board constitute most of the total production cost, it is important that the board is properly inspected before being etched. Otherwise, the wrongly etched board will be thrown away. This, in return, requires a system to detect online or in real-time any defect caused by the printing process.

1.1.3 Defects

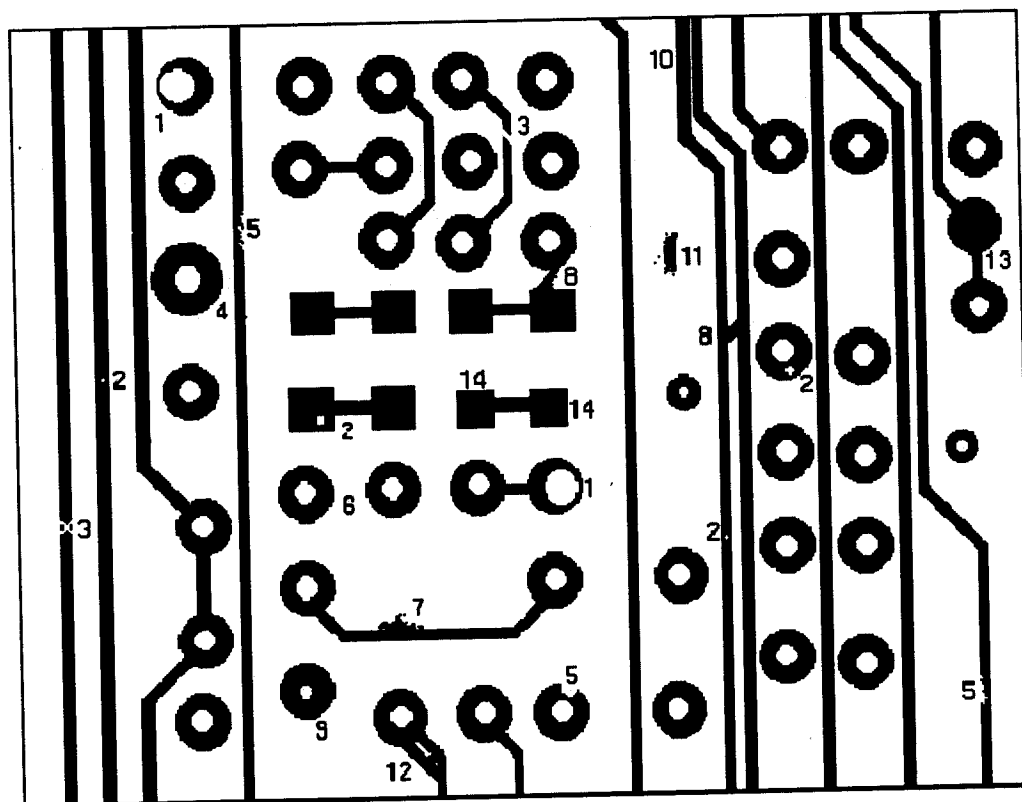
A variety of defects can affect the copper pattern of PCB. Some of them are identified as functional defects, whereas the others are visual defects. Functional defects seriously cause a damage to the PCB, meaning that the PCB does not function as needed. Visual defects do not affect the functionality of the PCB in short term. But in long period, the PCB will not perform well since the improper shape of the PCB circuit pattern could contribute to potential defects. Thus, it is crucial to detect these two types of defects in the inspection phase. Figure 1.2 (a) shows an artificial defect-free PCB image pattern. Figure 1.2 (b) shows the same image pattern as in Figure 1.2 (a) with a variety of defects on it. The printing defects and anomalies that will be looked at, for example, are breakout, short, pin hole, wrong size hole, open circuit, conductor too close, underetch, spurious copper, mousebite, excessive short, missing conductor, missing hole, spur and overetch. These defects are shown in Figure 1.2 (b).

1.2 Motivation

This thesis is motivated mainly by the need for more efficient techniques in inspection of the PCB panel in PCB fabrication process. Normally, a couple of operators are assigned in each station to manually check the PCB panels. This technique is not economic in a long run as it takes many man hours. In addition, humans are prone to make error especially due to fatigue. Moreover, it is impossible to check the entire PCB panels at every location without any delay. Instead, the printed laminate is sampled for a certain interval of quantity for manual inspection.



(a)



(b)

Figure 1.2 : (a) An example of good PCB patterns (b) An example of defective PCB patterns

As the electronic circuitary technology advances, the PCB pattern becomes denser and complicated to facilitate smaller end products. Thus, manual inspection is not applicable anymore. Meanwhile, the advances in computers in term of high speed, large memory and low cost have resulted in better and cheaper equipment for image processing. Hence, there exist a possibility of introducing and implementing an automated PCB inspection system to remove the subjective aspects of manual inspection. At the same time, the automated PCB inspection system provides real time assessment of the PCB panel.

From the literature review, it is noted that there has been an increasing number of applications for wavelets and multiresolution analysis including (but not limited to) image compression [2], image denoising [3] and edge detection [4]. Up till now there is still no clear advantages of wavelets in industrial inspection application, especially for PCB inspection. This is a secondary motivating factor for the thesis.

The emphasis here is on the improvement of inspection time using wavelet-based technique. The algorithm proposed in this thesis has been tested on three PCB sample images. The classification or analysis of the defects detected is beyond the scope of this thesis.

1.3 Objective

The objective of this thesis is to design and develop an algorithm for automated visual PCB inspection that will automatically detect and locate the printing defects occurred on printed circuit boards laminate. The primary concern of this project is to make use the advantages of wavelet, related to multiresolution analysis (MRA) in order to detect and locate the printing defects with a minimal inspection time experimentally. The technique proposed should produce the output that is suitable for defect classification stage. Once the algorithm is developed, it will be

tested with samples of PCB pattern. However, the defect classification and the actual implementation of the entire system are not covered in this thesis.

1.4 Scope Of Work

In designing and developing a new defect detection and localization algorithm for automated visual PCB inspection, the scopes of the project have been defined as follows:

1. The whole PCB manufacturing stages comprise of bare-board fabrication, loaded board assembly and soldering process. For every stage, an automated visual inspection can be applied to facilitate the reliability test of the product. The algorithm is designed for the inspection of bare PCB panels only. Apart from the area, research work related to the component insertion inspection and solder joints inspection can be revised in [5-10].
2. There are three types of printed circuit boards available today [1]. They are:
 - Single sided boards: where the entire circuit is laid on one side of the board and the holes should be drilled on the board for mounting of components or for interconnection of components.
 - Double sided boards: with the circuit on both sides of the board and electrical connection is establish by drilling holes through the board and plating copper through the holes.
 - Multilayer boards: two or more pieces of PCB panel are stacked up together. Electrical connections are established from one side to the other and to the inner layer by drilled holes, which are subsequently plated through with copper.

Although it is possible to apply the proposed algorithm for the inspection of multi-layer boards and also the double-sided boards, this project concentrates more on the single sided boards inspection for experimental purpose.

3. In real implementation, an actual PCB images are acquired by using a single or multiple CCD camera. Thus, the individual camera takes the whole or a part of the PCB image. However, in this thesis, the PCB images used for the experiments are either taken from the previous research work or synthetically generated.

4. Automatic PCB inspection algorithm is designed to detect any one of the 14 types of defects mentioned previously. These 14 types of defects are expected to occur after the printing process. Thus, the defects caused by design-rule violation and the defects classifications of defects detected are beyond the scope of the project.

5. The project emphasis on the development of an efficient and fast algorithm for hardware implementation. However, it is beyond the scope of the project to evaluate or design the actual system hardware.

1.5 Thesis Contributions

The main contribution of this thesis is the wavelet-based technique for industrial inspection application. The wavelet-based algorithm for PCB defect detection and localization that will be proposed in this thesis proves that wavelets can be used in an automated visual PCB inspection. In fact, wavelets provide an effective way for the computation of the defect detection and defect localization. From the wavelets point of view, Haar wavelet is chosen with the aim to speed up the inspection of PCBs by looking at the number of filter entry with no boundary solution to avoid the complexity of the wavelet computation.

The next contribution is the enhancement of the automated visual PCB inspection algorithm in term of inspection time. The inspection time achieved by using MATLAB as a platform shows that the inspection time of the algorithm can be much reduced experimentally to the existing algorithm. Hence, it is possible for an automated visual PCB inspection system to perform in real time inspection without degrading the functionality of the system.

1.6 Thesis Organization

This thesis is organized as follows. Chapter 2 gives some reviews of the background, mainly on the comprehensive approaches of the automated visual PCB inspection followed by the research methodology for the project. Chapter 3 describes mainly on the discrete wavelet transform for one and two-dimensional signals from the Fourier transform point of view. The wavelet transform is a core fundamental for the algorithm developed in this project. Chapter 4 concentrates on the development of wavelet-based defect detection and localization algorithm. For the defect detection, wavelet-based image difference operation is introduced. Then, the defect localization is executed where the computation is done on the coarse differenced image. The proposed algorithm relies on wavelet transform as discussed in Chapter 3. This approach is different from the existing approach. The computation of defect detection and localization is applied not to the full or fine resolution of image data but to the coarser images, which are the outputs of wavelet transform. The image difference operation is also addressed in this chapter. The results and findings obtained from the full resolution image difference operation, RLE-based technique and the proposed algorithm are covered in Chapter 5. The performances in term of defects detection, inspection time and defects localization are also presented in this chapter. Chapter 6 ends this thesis with the conclusions of the thesis as well as the research directions of the project. The references and also the appendices are placed at the back of this thesis. The appendices contain three published publications within the period of this research.